MONITORING OF CHANGES IN FISHPOND ECOSYSTEMS

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Abstract

The fishponds in Central Europe are shallow, man-made water bodies of different size. Management of fishponds did not change over several centuries since the 15th and 16th centuries, when most of the fishponds were built. In the 20th century, the changes in fishpond management resulted in an increase of fish production from about 50 kg/ha to more than 500 kg/ha. The long-term development of eutrophication of Czech fishponds is shown. The amount of fertilizers (N, P) applied, average concentration of total P and N, NO_3, NH_4, PO_4 and pH values from the 1930s until now are given. An increase in N and P results in an increase in chlorophyll concentration and decrease in light transparency. On the other hand, no substantial rise in nutrient concentration has been observed. In particular a high load of N does not result in an increase in total N concentration in the water. Dominance of blue-green algae appears to be more correlated with the ratio of N/P than with a lack of CO_2. A model experiment on the relationship between fish stock, size of *Daphnia* sp. and water quality is described. The experiment in several fishponds in Lower Austria shows how a fish stocking level estimated according to natural food supply may improve water quality in fish ponds.

Pokorný, J., G. Schlott, K. Schlott, L. Pechar & J. Koutníková: **Monitoring von Veränderungen in Fischteich-Ökosytemen**

Die Fischteiche in Zentraleuropa sind seichte künstliche Gewässer unterschiedlicher Größe. Seit dem 15. und 16. Jahrhundert, als die meisten Teiche angelegt worden waren, hat sich die Bewirtschaftungsform nicht geändert. Im 20. Jahrhundert stieg die Fischproduktion durch Veränderungen in der Teichwirtschaft von 50 kg/ha auf 500 kg/ha an. Die langfristige Entwicklung der Eutrophierung tschechischer Fischteiche wird gezeigt. Menge der Düngung (N, P), durchschnittliche Konzentration von Gesamt-P und N, Werte von NO_3, NH_4, PO_4 und pH seit 1930 werden angeführt. Zunahme von N und P führt zur Zunahme der Chlorophyllkonzentration und zur Abnahme der Lichtdurchlässigkeit. Es konnte aber keine bedeutende Erhöhung der Nährstoffkonzentration beobachtet werden. Besonders hohe Stickstofffrachten ergeben keinen Anstieg des Gesamt-N im Wasser. Die Dominanz von Blaualgen scheint mehr mit dem Verhätlnis N/P zu korrelieren als mit fehlendem CO_2. Ein Modellexperiment über die Zusammenhänge zwischen Fischbestand, *Daphnia* sp.-Größen und Wasserqualität werden beschrieben. Das an Fischteichen in Niederösterreich durchgeführte Experiment zeigt, wie Fischbestände, gemessen am natürlichen Nahrungsangebot, die Wasserqualität in Fischteichen verbessern könnten.

Pokorný, J., G. Schlott, K. Schlott, L. Pechar & J. Koutníková: **Monitorování změn rybničních ekosystémů**

Rybníky ve střední Evropě jsou mělké vodní nádrže o ploše jeden až několik set hektarů. Způsob obhospodařování rybníků se neměnil několik století od 15., 16. století, kdy byla většina rybníků postavena. Ve dvacátem století se způsob obhospodařování rybníků změnil natolik, že produkce ryb se zvýšila z cca 50 kg/ha na více než 500 kg/ha. V práci jsou uvedena množství aplikovaných hnojiv, průměrné koncentrace celkového dusíku, celkového fosforu, NO_3, NH_4, PO_4 a hodnot pH od 30tých let tohoto století do současnosti. Zvýšené dávky hnojiv vedou ke zvýšení koncentrace chlorofylu a snížení propustnosti světla, naproti tomu nebylo pozorováno podstatné zvýšení koncentrace živin. Zejména vysoké dávky dusíkatých hnojiv nevedou ke zvýšení koncentrace dusíku ve vodě. Dominance sinic se zdá být více korelovaná s poměrem N/P nežli s nedostatkem anorganického uhlíku. Popsán je modelový experiment zaměřený na studium vztahu velikosti rybí obsádky, velikosti dafnií a kvality vody. Tento experiment prováděný v několika menších rybnících v Dolním Rakousku prokázal jak volbou vhodné rybí obsádky založené na nabídce přirozené potravy lze zlepšit kvalitu vody v rybníce.

INTRODUCTION

The management of fishponds in Bohemia did not change for several hundred years since the 15th and 16th centuries, when most of the fishponds on the present territory of the Czech Republic were built.
However, management practices changed in the second half of the 19th century. The basis of modern management of Bohemian fishponds aimed at an increase in fish production, according to ŠUSTA (1898). In the 20th century, the changes in fishpond management resulted in an increase in fish production of an order of magnitude - from about 50 kg/ha to more than 500 kg/ha. Reliable information on fish production from the 15th century can be found in the State and town archives.
Long term changes in fishpond ecosystems caused by different management practices for fishponds and their catchments may be studied from records of fisheries. Since the 1930s the results of hydrobiological studies and hydrochemical data are also available. The relationship between fertilizing and fish production has been studied by HRBÁČEK (1969), KUBŮ (1975) and BUDEBA (1992). They showed relationships between fish production and the amount of fertilizers used (for some of the figures, see POKORNÝ et al. (1993)). The high correlation between the amount of fertilizers applied and the fish production is evident from the 1930's to the 1960's. In the past decades, the changes in nutrient load has not resulted in any changes in fish production. Recently, there is no correlation between the amount of fertilizers applied and the fish production. The high nutrient load brings about deterioration of water quality which negatively influences the fish stock and the stability of the whole pond ecosystem.
The changes in management practices may be considered as a long term ecosystem experiment. During this century, similar management practices, i.e. fishstocking and fertilizing, were used in a large number of fishponds.
The fishstock influences plankton structure, and therefore it influences indirectly other parameters of water quality, including abiotic parameters such as transparency and water chemistry (FOTT et al., 1980). The nutrient input both from fertilizers applied directly to fishponds and from the catchment increase the trophic level of fishponds. Changes in nutrient input and in the fish stock take place simultaneously and their individual roles in changes in water quality are very difficult to distinguish.
The aim of this study was to compare data on amount of fertilizers used from the 1930's until present with the amount of nutrients, pH, transparency and chlorophyll found in the water. In this way we aimed to evaluate the relationship between the amount of nutrients applied (load) and the water quality (i.e., the concentration of nutrients in the water etc.).
For one season, we evaluated the relationship between pH and chlorophyll a, and also the relationship among NO_3, NH_4 and PO_4 and blue green algae (cyanophytes), in order to test whether the development of blue green algae is controlled by lack of inorganic carbon or by the N/P ratio.
An example of a comparative study on fishpond management from Lower Austria is also given in order to demonstrate how optimalisation of fish stock may improve water quality.

METHODS

The data from the 1930's, 1950's, etc., on the amount of fertilizers used (load) and on the nutrient content in the water were taken from JÍROVEC & JÍROVCOVÁ (1938) and from the State Fisheries. Since the 1950's, standard methods of hydrobiological and hydrochemical analysis were recommended and mostly used for fish pond study. The methods used during that time are known and may be repeated, and the results from the 1950's and later may be compared in this way with recent results.

The recent data on pH, chlorophyll a, nutrient content in the water and cyanophyte biomass were collected from 90 ponds in TŘEBOŇ Biosphere Reserve 5 times during the season of 1992 (March 19, April 29, June 1, June 24, August 19). NH_4, NO_3 and PO_4 were estimated by Flow Injection Analysis using Tecator (RŮŽIČKA & HANSEN, 1981). Chlorophyll a was estimated in acetone + methanol (5 : 1) extract using a Turner fluorometer (10 - OOR). One sample from each pond was taken for determination of the main phytoplankton groups.

In Waldviertel fish ponds (Lower Austria), the species, amount and size of zooplankton were monitored during a season in order to optimalize amount of food and fertilizers applied. The water chemistry was also studied.

RESULTS AND DISCUSSION

Table 1 shows long term development of eutrophication of the Czech fishponds. The load means the amount of fertilizers applied

Year	Load N (kg/ha)	load P (kg/ha)	N : P
1930	0,1	0,3	0,2
1950	5,8	12,0	0,5
1960	5,0	4,8	1,0
1974	39,7	7,4	5,4
1979	12,2	4,0	3,1
1984	36,8	7,6	4,8
1990	41,0	8,3	4,9
1991	51,9	5,3	9,9

Table 1: Czech fishponds. Long-term development of eutrophication

by fishpond managers per hectare per year. The data were compiled from the records and documents of the State Fishery Blatná and represent the means from several decades of fish ponds. An increasing load of nitrogen (except 1979) and increasing N : P ratio are evident.

Table 2 shows average concentrations of total nitrogen and total phosphorus, transparency (Secchi disc depth) and chlorophyll a concentration in two regions of the Czech Republic from 1954 to 1993. Blatná is located in the Southwest and Třeboň Biosphere Reserve is in the South of the Czech Republic. The number of ponds evaluated is given under No. loc. (number of localities).

Table 2 shows an increase in total nitrogen of about 2.5 times from the 195O's to 1992 - 1993. The changes in the concentration of total phosphorus correspond to the decrease in the amount of mineral fertilizers applied in the 1970's. The rise of total phosphorus concentration in the 1990's results from the higher load of organic fertilizers. The transparency decreased from 1.7m to 0.52m, and a corresponding increase in the concentration of chlorophyll a (from 35 to 95 ug/l) is also shown in Table 2.

Table 3 shows average values of pH and average concentrations of NO_3, NH_4, PO_4 from 1954 to 1993 again in Třeboň and Blatná regions. Except for the value of NH_4 (1973-78, Třeboň), the concentrations oscillate around the values which are relatively low regarding the high nitrogen load increase from the 1950's to the 1990's and regarding the high chlorophyll content. The load of nitrogen has increased 10 times from the 1950's to the 1990's, although no rise in mineral nitrogen can be seen.

Figures 1a and 1b show relationships between the nitrogen (phosphorus) load and mean concentrations of total nitrogen (total phosphorus). It is evident from Figure 1a that an increasing load of nitrogen does not result in a proportional rise in total nitrogen concentration. On the other hand, an increasing load of phosphorus brings about a proportional rise in phosphorus concentrations as evident in Figure 1b.

High pH caused by photosynthetic activity of autotrophs can bring about fish-kills, particularly in late spring when higher concentrations of NH_4 occur. High pH is a

Period	Total N (mg/l)	Total P (mg/l)	Transparency (m)	Chl-a (µg/l)	No. loc.	Region
1954 - 1958	1,00	0,20	1,70	35	9	Blatná
1973 - 1978	1,27	0,11	1,27	66	10	Třeboň
1979 - 1980	1,55	0,12	0,97	48	33	Blatná
1990 - 1991	2,60	0,29	0,45	121	35	Třeboň
1992 - 1993	2,48	0,24	0,52	95	89	Třeboň

Table 2: Czech fishponds: Long-term development of eutrophication

Period	pH	NO_3-N (mg/l)	NH_4-N (mg/l)	PO_4-P (mg/l)	No. loc.	Region
1954 - 1958	8,3	0,07	0,09		9	Blatná
1973 - 1978	8,2	0,13	0,39	0,05	10	Třeboň
1979 - 1980	8,3	0,11	0,11	0,04	33	Blatná
1990 - 1991	8,5	0,12	0,12	0,05	35	Třeboň
1992 - 1993	8,2	0,14	0,23	0,09	89	Třeboň

Table 3: Czech fishponds. Long-term development of eutrophication

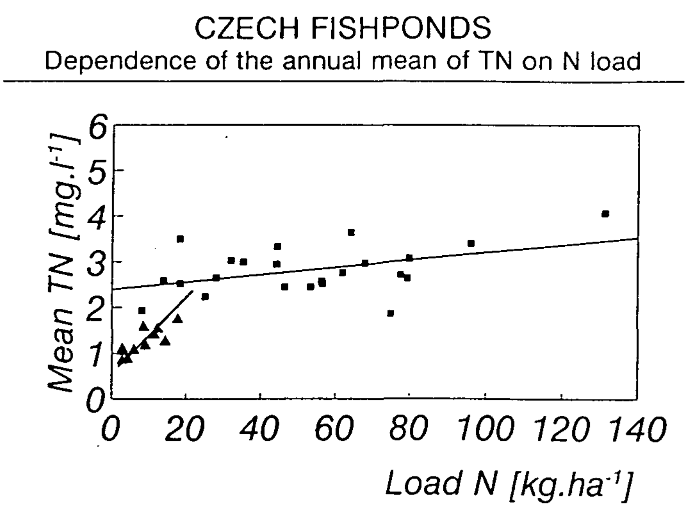


Fig.1a: Dependence of the annual mean total nitrogen concentration (TN) on the annual load of nitrogen (N)

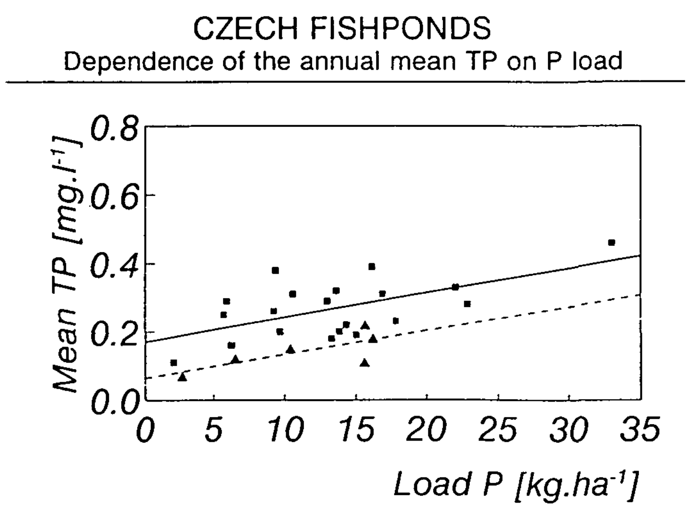


Fig.1b: Dependence of the annual mean total phosphorus concentration (TP) on the annual load of phosphorus (P)

consequence of intense inorganic carbon uptake by phytoplankton.
There are hypotheses which explain the dominance of blue green algae in eutrophic waters by the higher affinity of blue green algae to inorganic carbon. SHAPIRO (1990) explains the increasing portion of blue greens by their higher ability to take up inorganic carbon at higher pH than other phytoplankton groups. Therefore, the concentrations of chlorophyll a and pH values were measured in 91 ponds five times during the period March 19 to August 19, 1992. Figure 2 shows that pH does not follow the pattern of chlorophyll a concentrations. The highest pH values caused by photosynthesis have been found in spring.

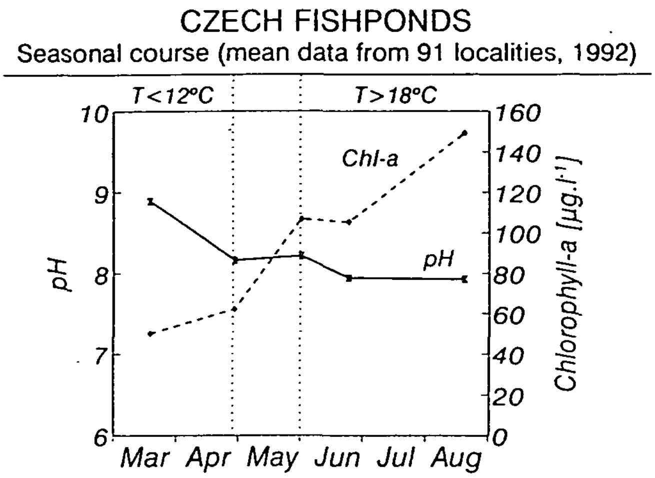


Fig. 2: Seasonal trends in pH and chlorophyll a concentration. The average water temperatures are indicated.

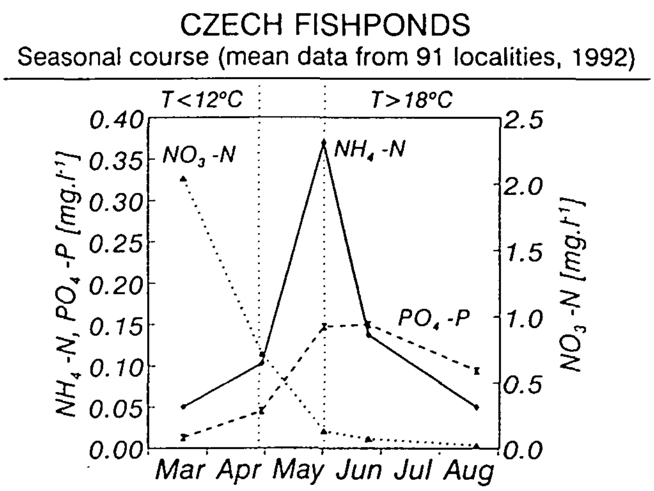


Fig. 3: Seasonal trends in ammonium nitrogen (NH_4-N), phosphate phosphorus (PO_4-P), and nitrate nitrogen (NO_3-N) concentrations. The average water temperature are indicated.

pH falls slightly from spring to late summer, whilst the chlorophyll concentrations, on the other hand, rise from March (50 ug/l) to August (150 ug/l). This discrepancy between increasing concentration of chlorophyll and decreasing values of pH may be explained by higher microbial (respiration) activity in warmer

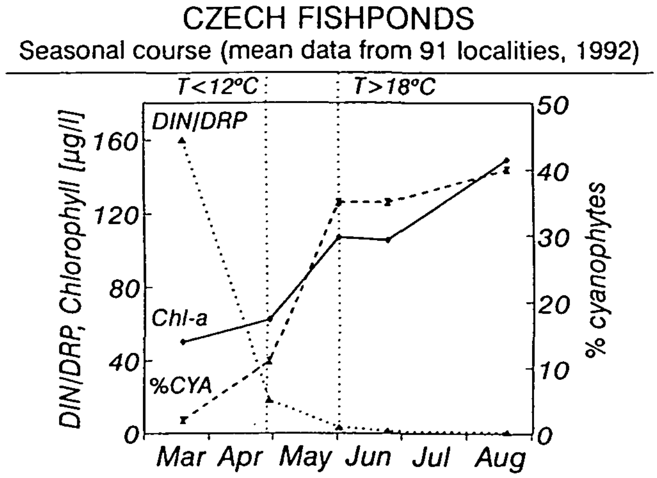


Fig. 4: Seasonal trends in chlorophyll-a, ratio of dissolved inorganic nitrogen (DIN)/dissolved reactive phosphorus concentrations and percentage of fish ponds in which cyanophytes (blue- green algae) dominate. The average water temperatures are indicated.

water in summer and by the different temperature dependence of photosynthesis and respiration: the rate of respiration increases with temperature more than photosynthesis.

The seasonal mean trends of nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N) and phosphate-phosphorus (PO_4-P) given in Figure 3 may be again explained by the temperature changes: denitrification and nitrate reduction by algae result in the nitrate concentration decrease. In addition, the external load of nitrate from the catchment decreases in late spring. The release of ammonium and phosphate from the bottom when the bottom is getting warmer, and application of organic fertilizers (containing NH_4) result in the ammonium and phosphate increase during May.

The differences between the responses of P and N are caused by NH_4 losses into atmosphere at high assimilatory pH, by denitrification in the bottom sediments which are rich in organic matter. Therefore, the high load of nitrogen fertilizers does not

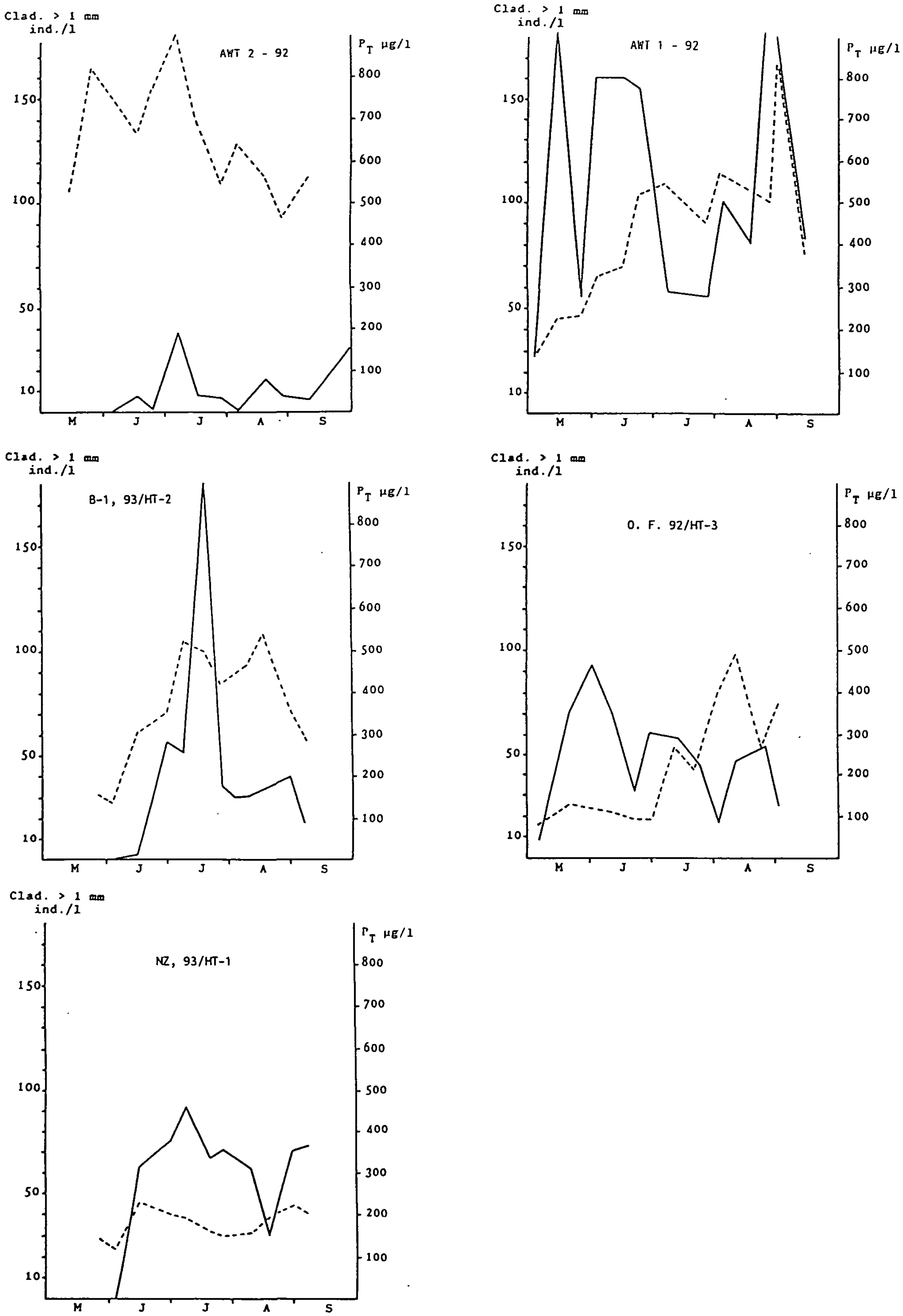
bring about a corresponding increase in total nitrogen concentration. The losses of nitrogen (in the form of NH_3 and N_2) and the accumulation of phosphorus in the bottom sediments bring about convenient conditions for the development of planktonic blue green algae. This trend is shown in Fig. 3. The NO_3 concentration is highest in spring. Later, nitrate is denitrificated or directly metabolized. The increase in NH_4 and PO_4 may be explained by their release from sediments.
Figure 4 demonstrates the dramatic change in the percentage of ponds in which the cyanophytes dominated (i.e. more than 4/5 of phytoplankton biomass consists of blue-green algae). It is evident from Figures 2 and 4 that the development of cyanophytes is more closely related to the decrease in the ratio of dissolved inorganic nitrogen to dissolved reactive phosphorus than to the lack of inorganic carbon. Despite no increase in pH during the season, cyanophytes are becoming more successful and their ratio rises from several percent in March to more than 40 % in August. These data show that in the case of our study, the N/P ratio is more important for the development of blue greens than the deficiency of CO_2. Fish stock is another reason of the higher ratio of cyanophytes - the high biomass of fish eliminates the large filter-feeding zooplankton (*Daphnia* spp.), allowing the development of dense phytoplankton. This massive development of phytoplankton results in further lowering of the N:P ratio and in further deterioration of the underwater light conditions. The high stock density of carp can thus stimulate development of shade-adapted blue-green algae in the phytoplankton community.

The presented results show that

a) the seasonal development of phytoplankton and concentration of nutrients differ from those described earlier by KOŘÍNEK et al. (1987)

b) the fishponds in Třeboň Biosphere Reserve can be considered as hypertrophic water bodies.

The next part of this article deals with the results of a model experiment on the relationship between fish stock, cladoceran number and size, and water quality.
The monitoring of fishponds must be closely connected to knowledge of fishpond management. Ahead of this conclusion, there is the hypothesis that proper functioning of ponds is possible only with a proper fish stock. The size of the fish stock should be balanced with the amount of nutrients and amount of natural food.
The number of large cladocerans is a representative parameter for the amount of natural food. Therefore the control of the *Daphnia* population and its interpretation regarding the ecological circumstances should be an essential point of monitoring.
Figures 5 - 9 show results of the modelling experiment in which five fishponds were studied during one season. Number of large cladocerans (*Daphnia* larger than 1 mm) and total phosphorus content in the water were analysed during the season. The annual production of fish, the amount of food applied and feed conversion ratio were also estimated. Table 4 shows that a large fish stock and a large amount of food applied brings about high values of total phosphorus (635 ug/l). Figure 8 shows the situation when the size of the fish stock was balanced with natural food supply. The consumption of large *Daphnia* by fish was balanced in this case with the growth and natality rate of *Daphnia,* and the concentration of total phosphorus was lowest of all the ponds studied.
The crucial point for the sustainable use of fishponds in the future is to find the most effective way of transforming nutrients to fish production. The use of additional food has to be harmonised with the amount of natural food. Figure 7 shows another example - feeding was stopped when the number of *Daphnia* was rather high in July.



Figs. 5-9: Comparison of the number of large *Cladocera* (______) and concentration of total phosphorus (-----------). For fish production, additional feeding etc., see Table 4.

Pond	Annual production kg/ha	Amount of food (grain, pellets) kg/ha	Food conversion ratio	Total phosphorus µg/l mean value May-Sept.
AWT 2 / 1992	1560	2540	1,62	635
AWT 1 / 1992	650	1350	2,08	445
B-1, 93 / HT-2	760	1090	1,44	367
NZ, 93 / HT-1	140 (natural prod.)	-	-	178
O.F. 92 / HT-3	no fish stock	-	-	219

Table 4: Annual fish production, amount of food, FCR and total phosphorus content.

An immediate decrease in *Daphnia* is evident and a reduction in the concentration of total phosphorus followed. The feed conversion coefficient and the concentration of total phosphorus were lower than in the previous two cases, and the total annual production was even higher than in the second case.

CONCLUSIONS

The data and results presented in this paper represent survey not monitoring. The following conclusions may be made from these data:

1) No marked changes in dissolved inorganic nutrient content have been found from the 1950's to the present time. Changes have been found in water transparency and in the amount of chlorophyll.
2) The increasing load of phosphorus brings about the increase in phosphorus concentration. On the other hand, the increasing load of nitrogen does not bring about any increase in nitrogen concentration.
3) During a season no increase in average pH (decrease in inorganic carbon) has been observed in eutrophic ponds. The higher percentage of blue greens in summer seems to be better correlated with the DIN/DRP (dissolved inorganic nitrogen/ dissolved reactive phosphorus) ratio which decreases markedly during the season.
4)The size of fishstock in fishponds should be taken into account when interpreting any monitoring data for fish ponds. It has been demonstrated how optimal use of natural food by fish results in a reduction in total phosphorus.

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